Operational Developments at JLAB

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Overview: Operations at JLab
Beam Quality
12 GeV transitional issues
Directions for Development

The CEBAF Accelerator

- 5-Pass Recirculating (Folded) Linac
- Fixed target use
- Superconducting Accelerator
  - high duty factor (CW; sub-harmonic as needed)
  - maximize current to users
  - minimum accidental coincidence rate
- Polarized beam
- Requires: stable current, low helicity correlations

Beam Delivery Requirements

- Multiple concurrent user experiments
- Beam Power < 800 kW (dump limitation)
- Typical currents 0.001 to 100. microAmp
- Current stability ~few % level usually
- Position stability typically ~50 microns
- Energy stability/spread 2.e-5 – 1.e-4

User Issues

- Experimental duration 1wk to 1 yr (scale)
- General purpose detectors in Halls
- Dedicated installation for long-term special needs
- Installation coordination
  - Initially by Hall staff
  - Later by experimental staff
  - Now by joint group
  - reduced chance of “Oh, didn’t you know about that?”

Legacy Issues

- The facility is young, but still has legacies
  - Early installation done on tight budget, no overall integration from hardware to model
  - Attempting to transition into GIS framework and improve model of accelerator
  - Diagnostic techniques still need improvement

operational integration efforts

- 8:00 am daily meetings preceded by 7:45 experimental run coordinator meetings
- Program Deputy role filled by physics/admin/ops
- specific experiment:operations coordination
  - G0 coordination model
- Operations staff 24x7 during run period
- Other groups on-call (E. Gun Group, CASA, engineering technical support)

JLab operations

- relies on experts rather than ops staff expertise, attrition of experienced operators
- "setup" and "run" are different modes
- quality monitoring tools largely non-integrated with rest of system; no common data source
- configuration based on historical settings rather than being analyzed for "correct" values
- these issues must be addressed in the near future

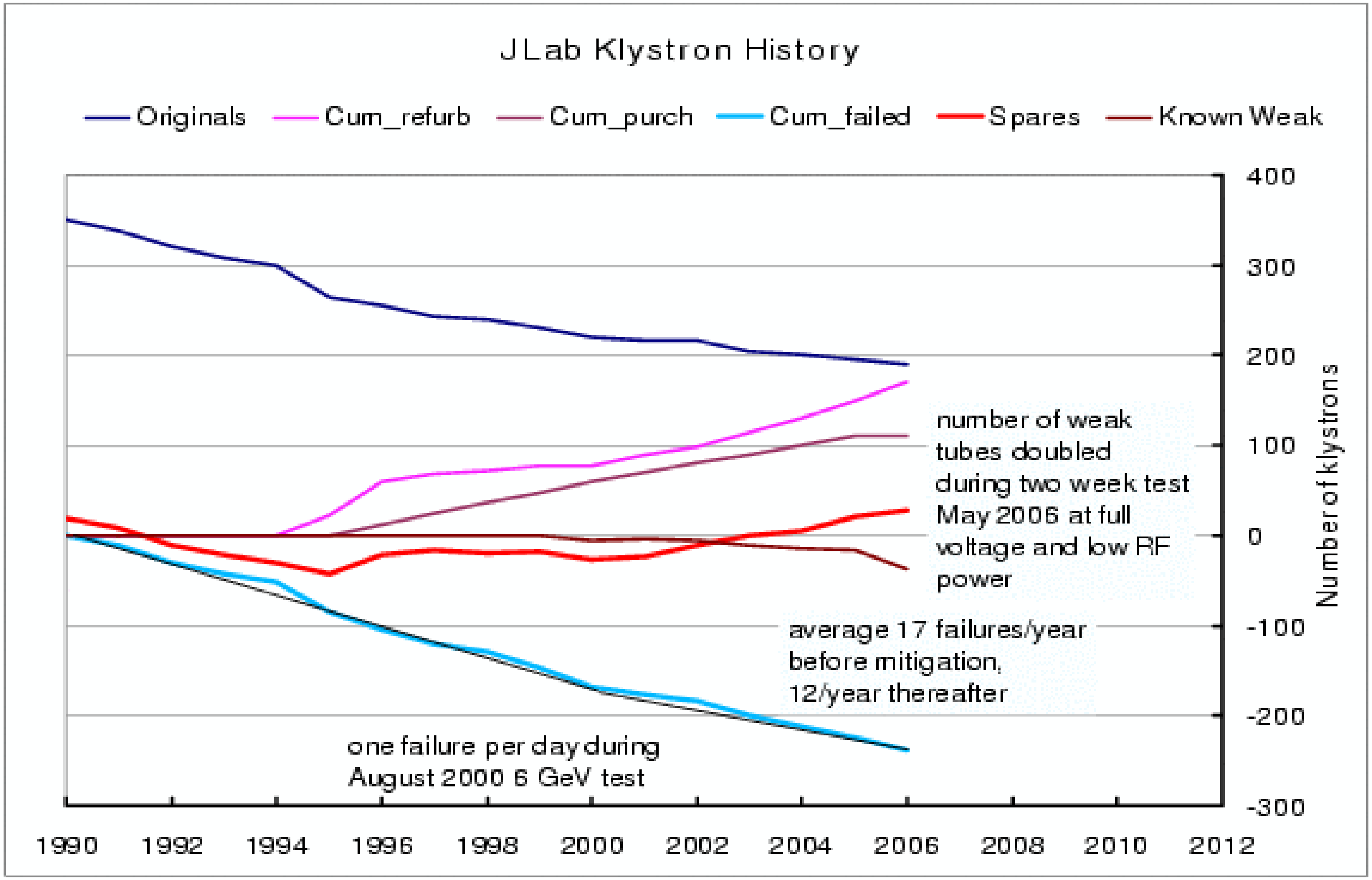
MCC – “The Wall”

Technical developments (non-beam)

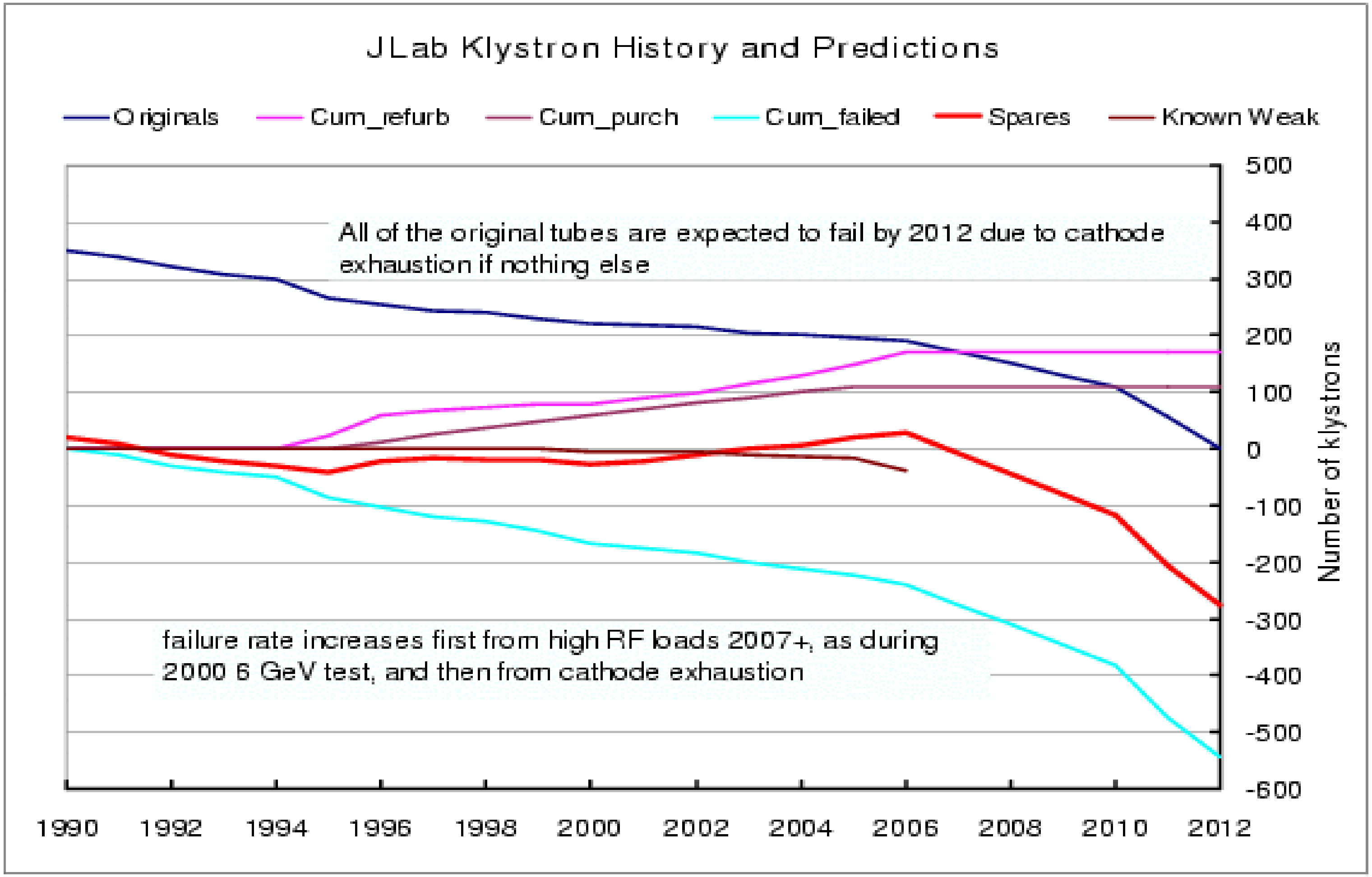
- Site power demand
- Klystron lifetime tracking and management
- Cryogenic plant efficiency increases (cryo group)
- Cryomodule upgrades, 12 GeV upgrades
- Asymmetric linacs
  - Equal-linac configuration: unnecessary limit
  - Avoids juggling cryomodules
  - To be tested this week: linac ratio ~ 1.1 : 1

Infrastructure Monitoring (Hardware)

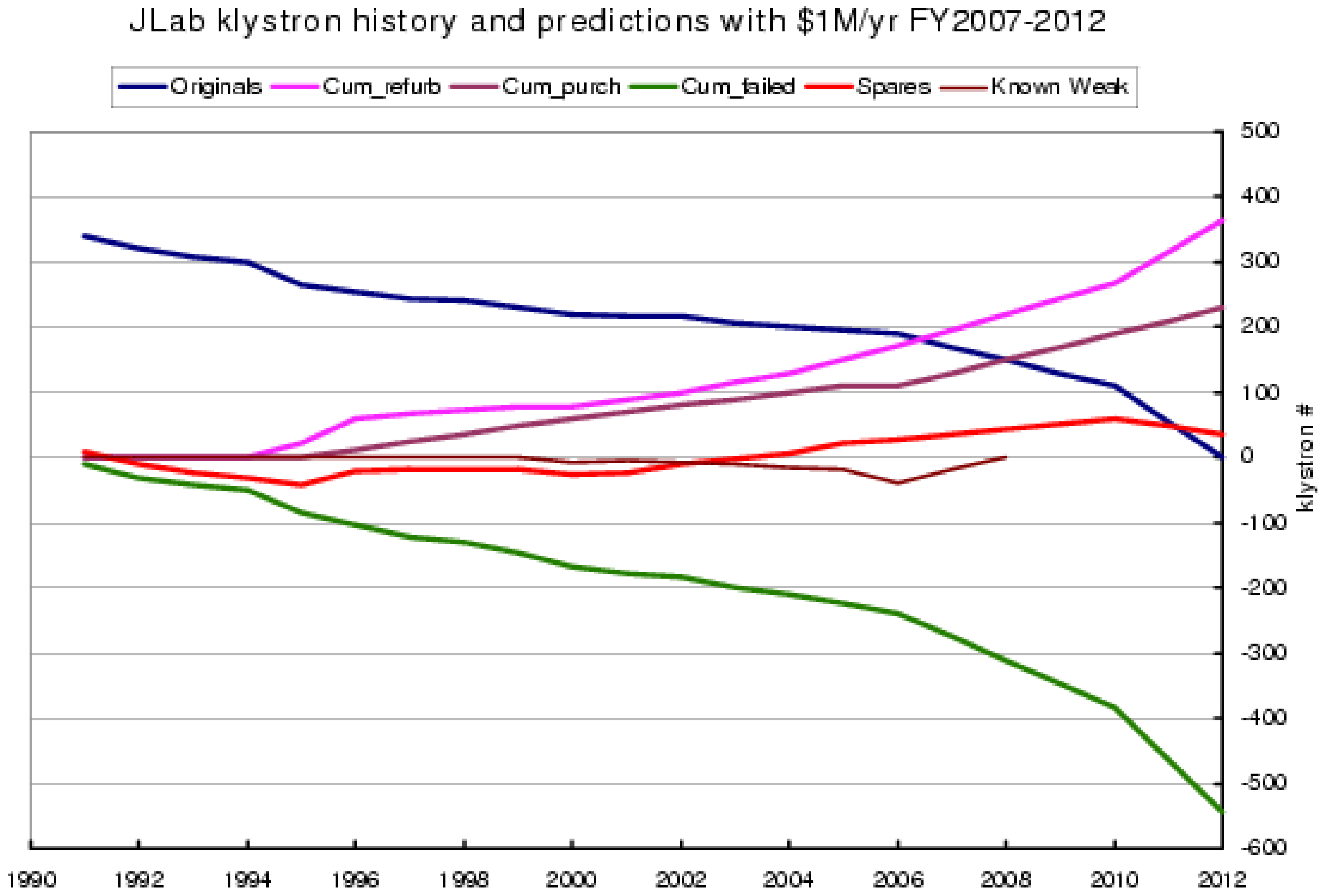
- Klystron lifetime and failure rates/modes
- Klystrons are well beyond their expected life
- JLab carefully tends & conserves them
- Tubes used in normal conducting system near full rated power have ~30000 hr lifetimes
- Anticipated energy increases will tax tubes heavily and require stepped up purchases



Spares is the difference between needed complement (CEBAF and FEL) and the number of good tubes on hand. During the decade it was negative, poor and non-functional cavities had tubes removed to keep the best cavities in service.



Conclusion: Physics program at risk beginning November 2007 without doing something.


JLab klystron history and predictions with $1M/yr FY2007-2012
Originals
Cum_refurb
Cum_purch
Cum_failed
Spares
Known Weak
500
400
300
200
100
0
-100
-200
-300
-400
-500
-600
klystron #
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012

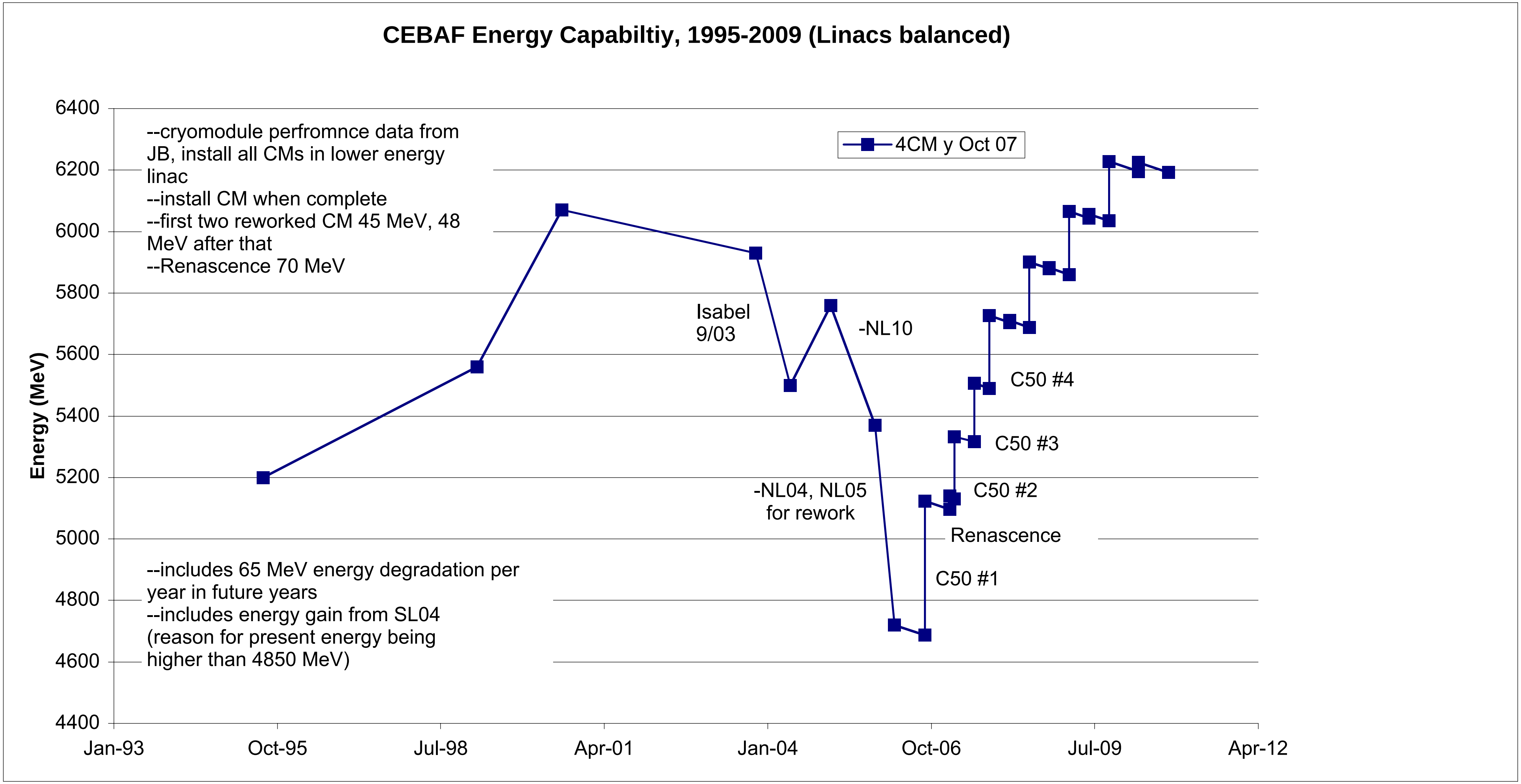
Operations Overview FY05/06

- Operated at 0.9 GeV/pass thru September 2005, 1.04 GeV/pass thru December 2005
  - Relatively easy running
- Started low-energy run (~0.75 GeV/pass) in March 2006
  - Set up was difficult and time-consuming
  - Much hardware could be turned off
    - Result – exceptional hardware availability
- Aggressive program of CHL power reduction saved us
  - CHL developed improved operating mode

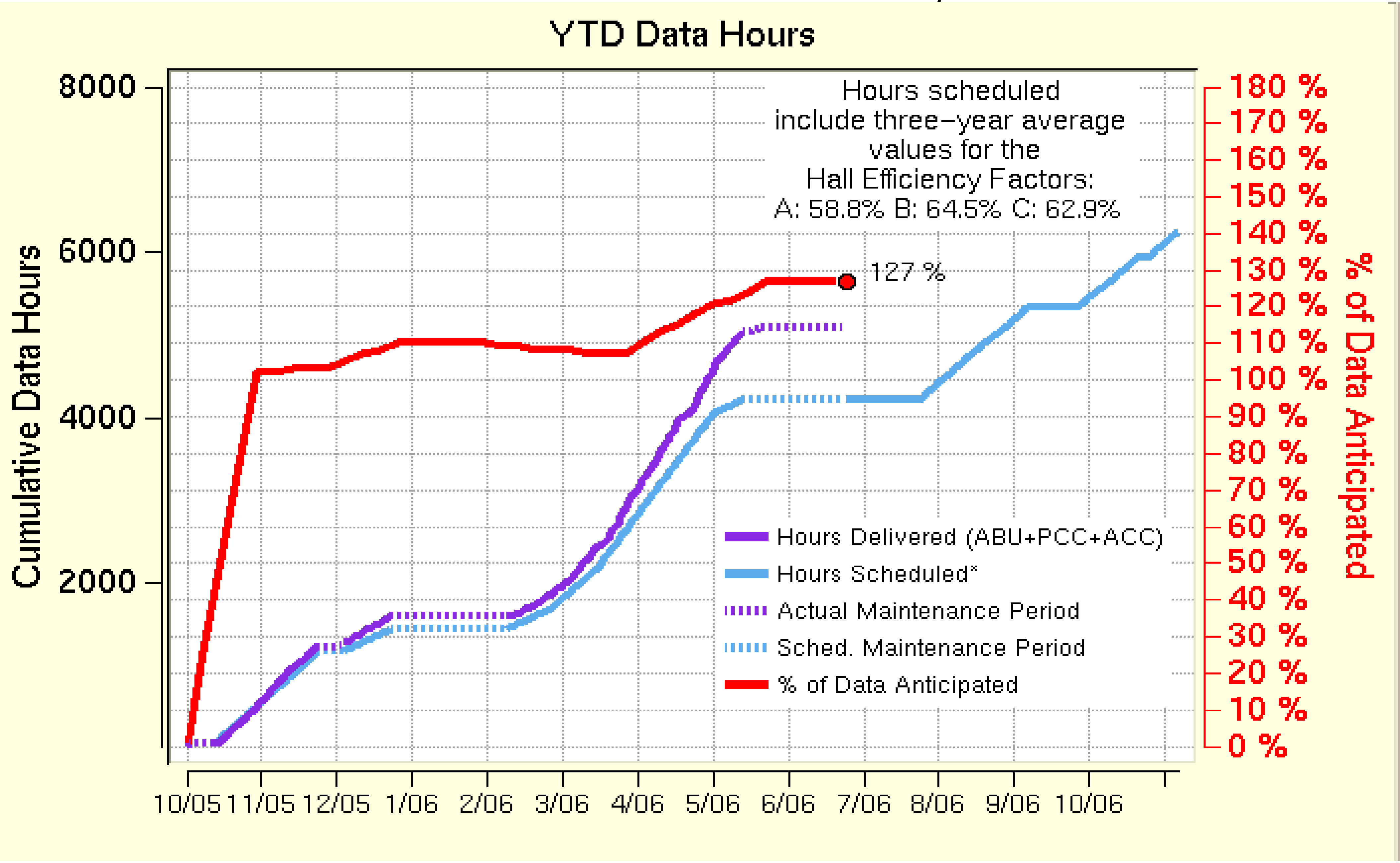
Cryomodule refurbishment program

- Partly AIP funded rework of existing modules to 50 MV (12.5 MV/m).
- Program hit badly by FY06 funding shortfall.
- Projected rate fell to ~1.25/yr. Insufficient to meet 07/08 physics program.
- Reserve funds redirected to restore this activity at 3/yr rate.
- Plan supports high energy running beginning 07.
- Rework continues until 12 GeV project starts, provides solid 6 GeV base.
- Minimal changes only, doglegs to eliminate trips, renew worn parts.

CEBAF energy 1995-2009



Accumulated Data thru May for FY06



JLab Cryogenic Technology Focus

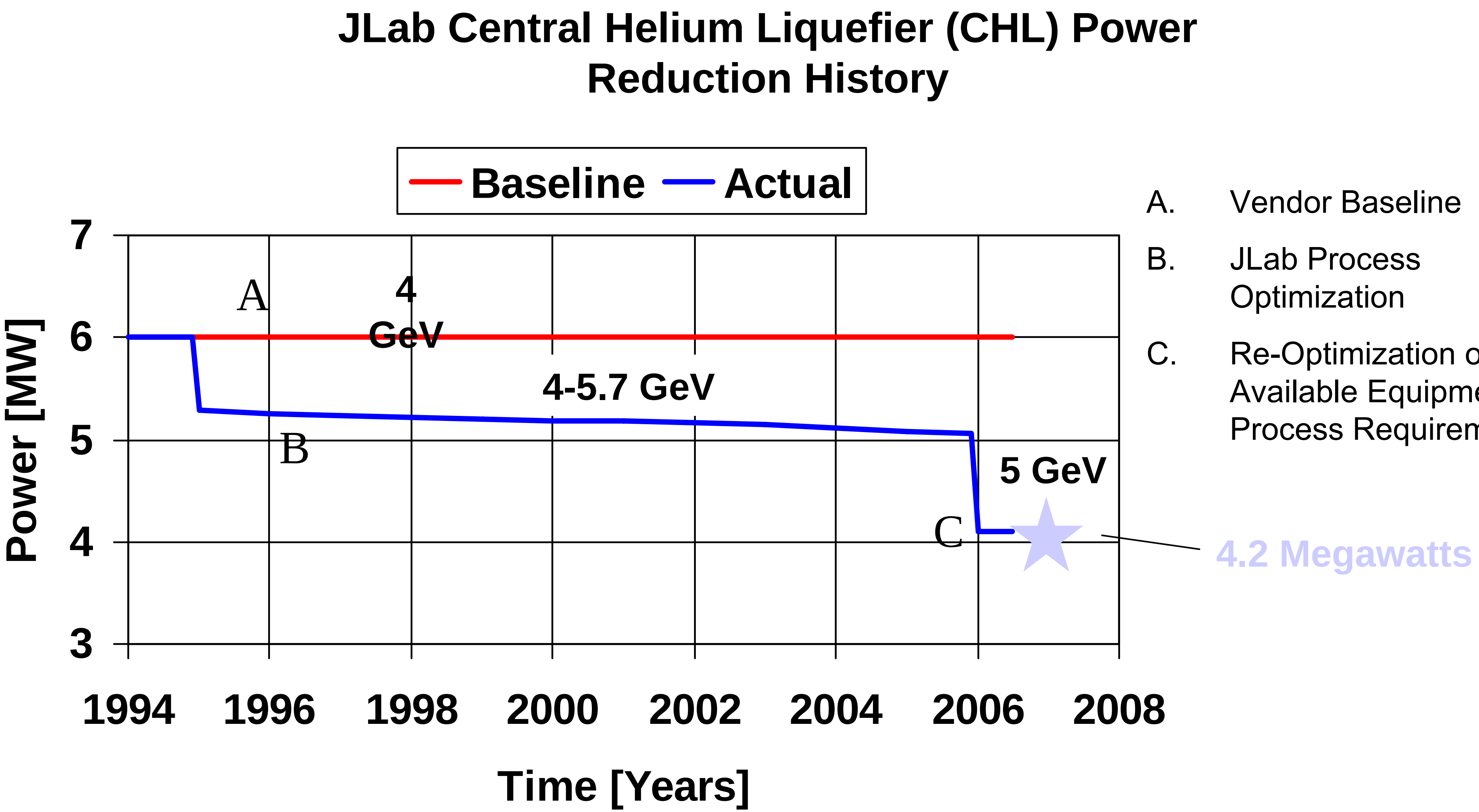
Use JLab's Cryogenic Technical Core Competency to:

- Provide safe, reliable, cost effective, and environmentally responsible cryogenic helium plant operation and future resource planning for the laboratory. (Operation of its three current large 2K and 4K Cryogenic Helium Plant Facilities, future plan for doubling current 4600 W 2K plant for 12 GeV)
- Provide continuous design and operational advancements of 2K and 4K helium cryogenic technology, both internally and through technical collaborations with other research laboratories and industrial partnerships.
- Reduce plant utility costs through efficiency improvements to curb rising energy costs.
- Promote cryogenic technology and individual advancements by formal and informal education in the field of cryogenics in support of the research community.

Medium and Long Term R&D

- **JLab Ganni Helium Refrigeration Process Cycle:**
  - **New JLab (Patent Pending) Technology**
  - **2K and 4K Process Cycle**
  - **New Plant Applications (12 GeV, ERL, ILC, etc.)**
  - **Lower Capital Equipment Cost**
  - **Highest System Efficiency For All Full and Part Load Conditions (matched and maintained peak warm compressor efficiency to turbine efficiency)**
  - **Uses of Jlab's "Equal Carnot Step" system design approach**
  - **Technically evaluated by industry**
  - **Commercial License negotiations underway**
- **Post Commissioning System Optimization**
  - **Actual Sub-Component Performance Analysis and System Remodeling to take advantage of component strengths**

FY2006 Technical Accomplishments



A. Vendor Baseline

B. JLab Process Optimization

C. Re-Optimization of Available Equipment and Process Requirements

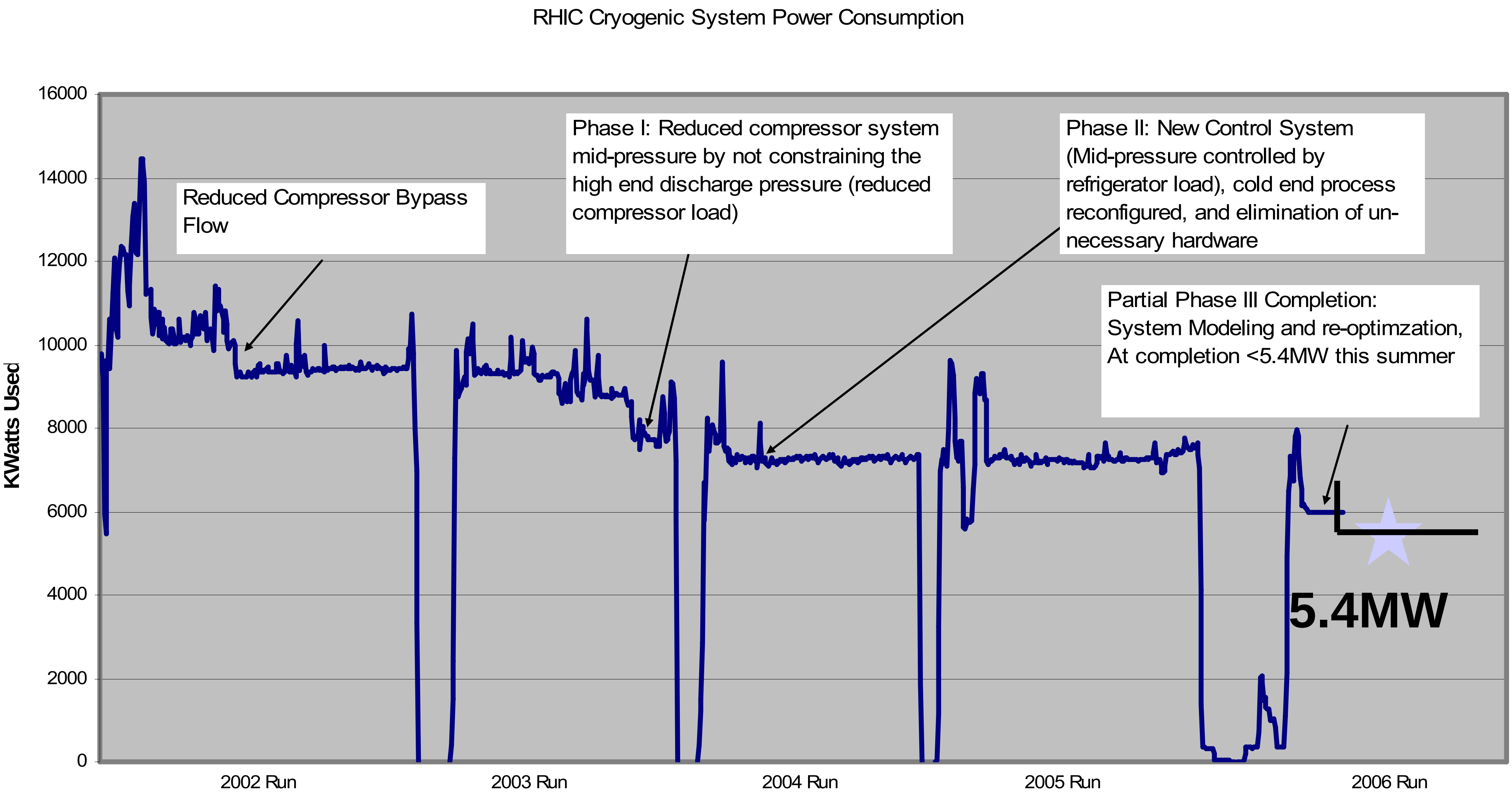
A

FY2006 JLab Technical Collaborations

- **RHIC Phase III Energy Conservation Program, WFO**
  - 2006 Electrical Power Reduction ~1.2 megawatts with partial phase completion, another 0.6 megawatts expected summer 2006
  - Elimination of accelerator ring liquid helium circulator pumps as unnecessary with remodeled cycle adjustments
  - Remarked drop in mechanical failures and needed maintenance
- **SNS CHL Post Commissioning Optimization, WFO**
  - Electric power reduction from 3.8 to 2.6 megawatts (32%)
  - Optimization continuing based on data collected, Results used to reduce JLab CHL electrical power

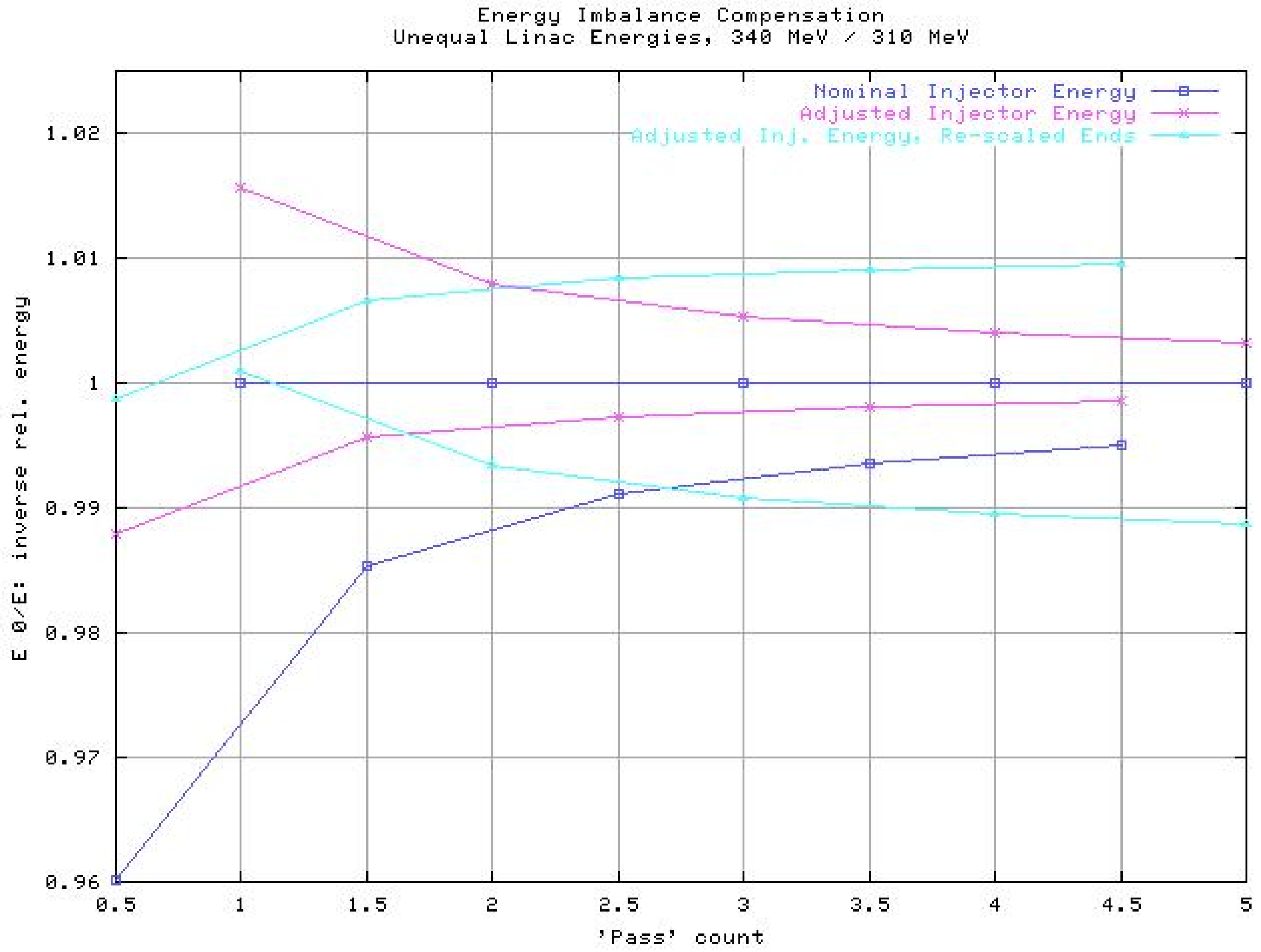
Jlab/BNL Energy Conservation Collaboration at BNL (RHIC)

45% Electric Power Reduction



Linac energy balance: ! or ?

- All operations to date used equal linac energy
- Leaves unused margin in stronger linac
- During upgrade, linac capacities will be unequal
- Hardware failures can also weaken a linac
- Design Limitations – coincident linac beam path
- Injector/Linac energies scale linearly 45:400:400
- 45(inj) 445 1245 2045 2845 3645
- 845 1645 2445 3245 4045


Energy Imbalance Compensation
Unequal Linac Energies, 340 MeV / 310 MeV
Nominal Injector Energy
Adjusted Injector Energy
Adjusted Inj. Energy, Re-scaled Ends
E 0/E: inverse rel. energy
'Pass' count
1.02
1.01
1
0.99
0.98
0.97
0.96
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

Adapting to unequal linac energy

- West End unchanged with unequal linacs
- Momentum mismatch equalized between East and West ends by changing Injector energy
- Re-scale East and West ends: re-match 1st pass
- Higher passes have smaller dispersion and tolerate greater momentum mismatch.
- Use existing shunt capacity (common buss) to re-steer beam to near center of beam line

Technical developments (beam)

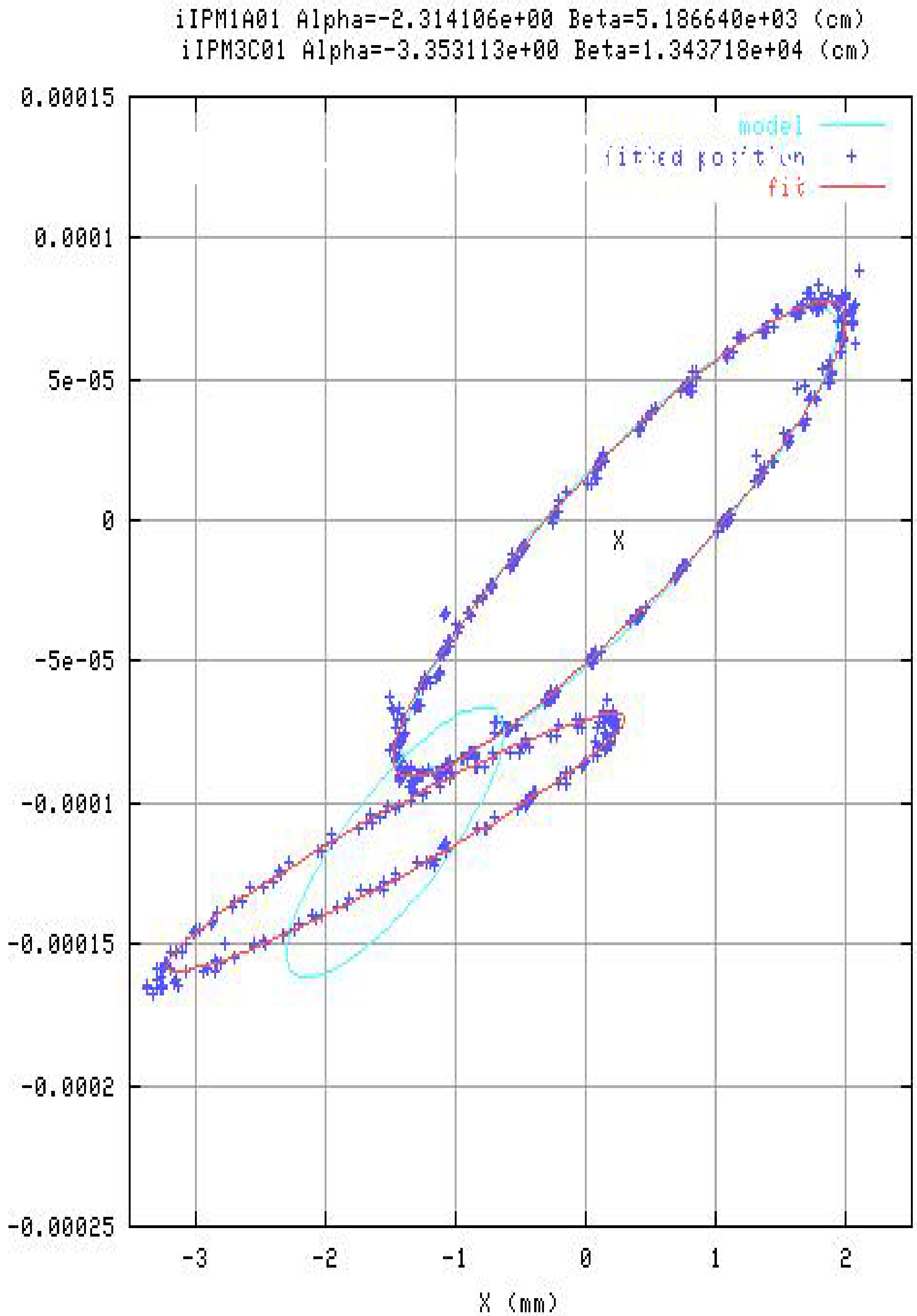
- Diagnostics – minor upgrades, limited budget
  - total current (tungsten slug calorimeter)
- Envelope matching with BPMs (raytrace)
- Helicity correlated beam properties
  - Current (parts per million)
  - Position (nanometer scale helicity, time-averaged)
  - Size (near future, diagnostic pending)

Optical Tuning Techniques

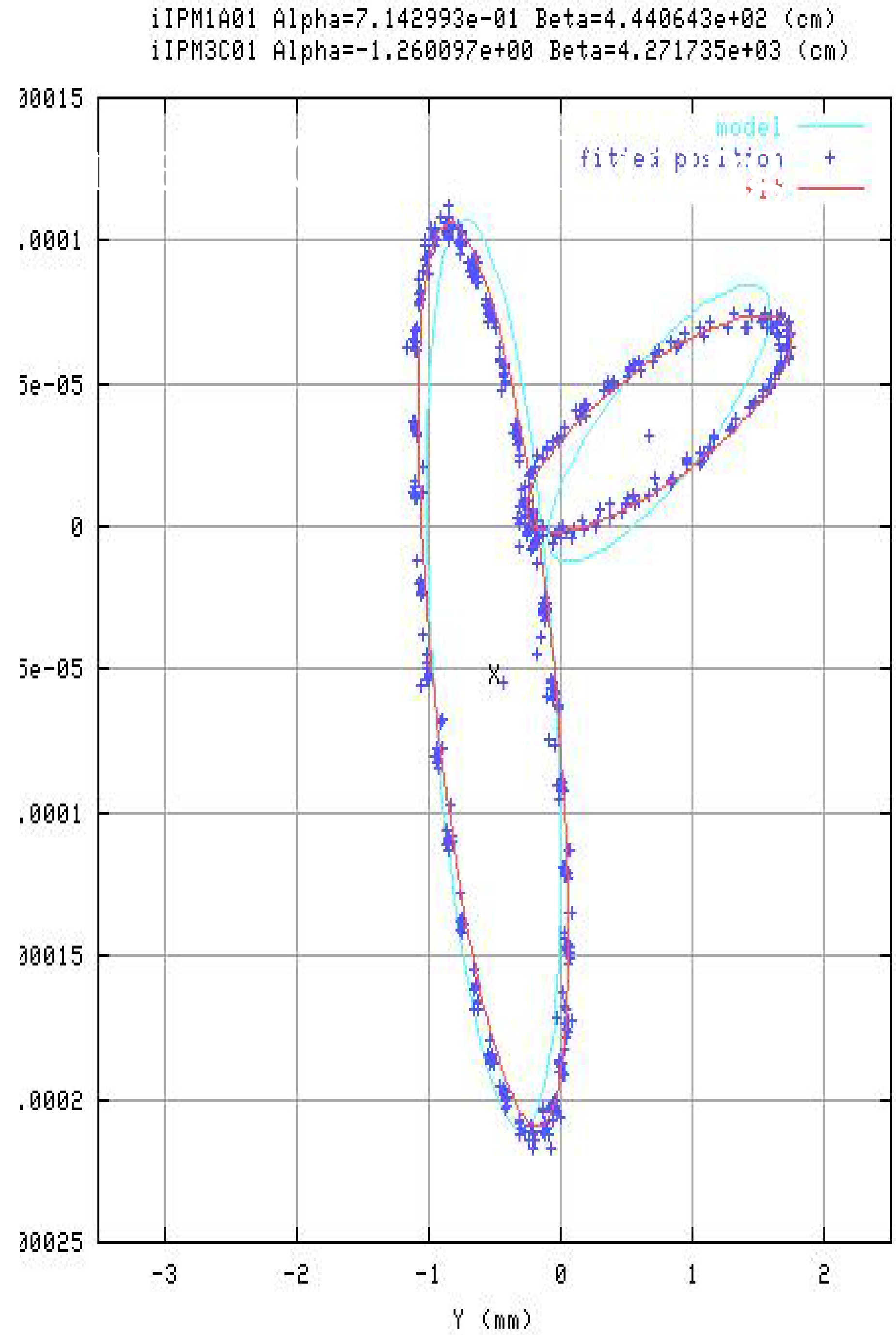
- Download Optics configuration
- Modulate beam angle at two positions in each plane (sequential use of each of four magnets)
- Compare downstream "Courant-Snyder" action parameter with expected value from injection
- Tuning quadrupoles designated to restore envelopes (not phases) to design values

Recent Improvements - RayTrace

- Large mismatches can be invisible with the standard sparse sampling of orbits at JLab
- Instead, inject a set of initial orbits, coordinating two correctors – a synthetic beam
- BPM system to detects differential orbits
- Short-range model generates (x,x') distribution of pseudo-beam “rays” downstream



iIPM1A01 Alpha=-2.314106e+00 Beta=5.186640e+03 (cm)
iIPM3C01 Alpha=-3.353113e+00 Beta=1.343718e+04 (cm)
model
fitted position
fit
X
0.00015
0.0001
5e-05
0
-5e-05
-0.0001
-0.00015
-0.0002
-0.00025
-3
-2
-1
0
1
2
X (mm)
X' (rad)



iIPM1A01 Alpha=7.142993e-01 Beta=4.440643e+02 (cm)
iIPM3C01 Alpha=-1.260097e+00 Beta=4.271735e+03 (cm)
model
X
0
-3
-2
-1
0
1
2
Y (mm)

RayTrace – open ended systems

- Downstream ray bundle shows directly the transformed (alpha, beta) and pseudo-emittance
- Shows cumulative envelope distortions resulting from optical errors
- Shows local optical errors, available at all BPMs
- Guides optics correction
- Helpful for open-ended linac system

Plans to Reduce Tuning Time

- Develop structured basis for controls software
  - Create GIS-compatible drawings*
- Finalize accelerator model
  - Develop accurate field maps for main magnet types
  - Develop and integrate tuning tools (ray trace, fopt)

* GIS = Geographical Information System